

Kai Liu

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Education

Ph. D., in Physics, Tsinghua University, Beijing, China	2008
B. S., in Applied Physics, Xi'an Jiaotong University, Xi'an, China	2003

Research Experience

2015.05-Present, *Associate Professor*, School of Materials Science and Engineering, Tsinghua University
2011.02-2015.05, *Postdoctoral Fellow*, Lawrence Berkeley National Lab & UC, Berkeley
2008.08-2011.01, *Postdoctoral Fellow*, Department of Chemistry, Tsinghua University

Awards and Honors

Frontiers Materials Young Scientist Award, International Union of Materials Research Societies	2021
Science and Technology Award (First Prize), Chinese Materials Research Society	2020
Rising Star Speaker Award (First Prize), ICMAT 2019	2019
Fok Ying Tung Foundation for Young Teachers	2018
National Outstanding Doctoral Dissertation Award (100 winners nation-wide)	2010
Academic Rising Star Award, Tsinghua University (Top 10 winners of graduate students)	2008
Excellent Ph.D. Graduates Award, Tsinghua University	2008

Professional Activities

- Aug. 2020-Present, **Editorial Board Member** and **Young Scientist Committee** of *Chinese Physics Letters*, *Chinese Physics B*, *Acta Physica Sinica*, and *Physics*.
 - Nov. 2020-Present, **Guest Editor** of *Nanomaterials* (IF=4.034) for the special issue "State-of-the-Art of Nanocomposite Materials in China".
 - Feb. 2020-Aug. 2020, **Guest Editor** of *Journal of Applied Physics* (IF=2.286) for the special issue "Phase-Change Materials: Syntheses, Fundamentals, and Applications".
 - **Peer Reviewer** for more than 100 papers submitted to *Nature Materials*, *Nature Communications*, *Science Advances*, *Advanced Materials*, *Angewandte Chemie International Edition*, etc., since 2015.
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Research Summary

- Focus on interface engineering of low-dimensional materials and heterostructures.
- Published more than 120 papers in *Science*, *Nature Communications*, *Science Advances*, *Advanced Materials*, *Materials Today*, *Nano Letters*, *Advanced Functional Materials*, *ACS Nano*, etc.
- Cited by over 7,500 times, H index is 40

(1) Interface strain engineering of low-dimensional materials

Interface strain deforms materials or even causes structural failure, and could dramatically modulate the properties of low-dimensional materials and affect their device performance. We investigate effects of interface strain in two-dimensional (2D) materials and interfaces. In our systematic studies of elastic properties of 2D materials (MoS₂, MoTe₂, etc.), we probed and controlled the strain-induced deformation (buckling) and fracture of these materials. We further engineered different interface geometries, including building bimorph structures and asymmetrically roughened interfaces, to modulate interface strain and realize applications in high-performance actuators and high-sensitivity tactile sensors.

(2) Engineering hetero-interfaces for high-efficiency sensing devices

Heterostructures are fundamental blocks in modern semiconductor devices. Engineering the hetero-interfaces in heterostructures can not only improve the device performance, but enable new functions in devices. We explore a novel type of hybrid heterostructures, *i.e.*, transition metal chalcogenide (TMD)/oxide (TMO) heterostructures. We combine the merit of thickness dependence of properties in the former and rich correlated electron effects in the latter, to realize high efficiency and multiple functions of heterostructural devices. Employing techniques of van der Waals stacking, natural oxidization, and direct laser writing, we fabricated a variety of TMD/TMO heterostructures, such as vertical WSe₂/VO₂, vertical NbS₂/NbO_x, and lateral NbS₂/Nb₂O₅, for dual-mode photodetectors and high-sensitivity gas sensors.

(3) Engineering interfaces for materials and devices working in harsh environments

Emerging applications in artificial intelligence or space exploration usually request materials or devices to work in harsh or extreme environments (particle irradiation, high/low temperature, etc.). However, low-dimensional materials are less stable due to their high surface-to-volume ratio, and thus are not expected to work well in these environments. The key strategy to address this problem is interface engineering, which can effectively stabilize the system or generate new nanostructures. We found that compared to single-layer material, multilayer graphene and MoS₂/graphene heterostructure are more “robust” in either elastic modulus or photoluminescence energy under high-energy particle irradiation owing to interfacial mutual enforcements. Taking advantages of the interface van der Waals forces, we also developed a lightweight, solid tape made of carbon nanotube films that are capable of working at extreme temperatures (-196°C~1000°C).

Selective Publications

1. Wu, Yonghuang; Xin, Zeqin; Zhang, Zhibin; Wang, Bolun; Peng, Ruixuan; Wang, Enze; Shi, Run; Liu, Yiqun; Guo, Jing; Liu, Kaihui; **Liu, Kai***. All-transfer electrode interface engineering towards harsh-environment-resistant MoS₂ field-effect transistors. *Advanced Materials*, 2023, in press.
2. Sun, Yufei; Wang, Yujia; Wang, Enze; Wang, Bolun; Zhao, Hengyi; Zeng, Yongpan; Zhang, Qinghua; Wu, Yonghuang; Gu, Lin; Li, Xiaoyan*; **Liu, Kai***. Determining the interlayer shearing in twisted bilayer MoS₂ by nanoindentation. *Nature Communications*, 2022, 13, 3898.
3. Li, Chenyu; Wang, Zhijie; Liu, Mingda; Wang, Enze; Wang, Bolun; Xu, Longlong; Jiang, Kaili; Fan, Shoushan; Sun, Yinghui*; Li, Jia*; **Liu, Kai***. *Nature Communications*, 2022, 13, 3338.
4. Wang, Enze; Chen, Zekun; Shi, Run; Xiong, Zixin; Xin, Zeqin; Wang, Bolun; Guo, Jing; Peng, Ruixuan; Wu, Yonghuang; Li, Chenyu; Ren, Hongtao; Li, Xiaoyan*; **Liu, Kai***. Humidity-Controlled Dynamic Engineering of Buckling Dimensionality in MoS₂ Thin Films. *ACS Nano*, 2022, 16, 14157.
5. Wang, Xuewen; Wang, Bolun; Zhang, Qinghua; Sun, Yufei; Wang, Enze; Luo, Hao; Wu, Yonghuang;

- Gu, Lin; Li, Huanglong; **Liu, Kai***. Grain-Boundary Engineering of Monolayer MoS₂ for Energy-Efficient Lateral Synaptic Devices. *Advanced Materials*, 2021, 33, 2102435.
6. Ma, He; Xiao, Xiao; Wang, Yu; Sun, Yufei; Wang, Bolun; Gao, Xinyu; Wang, Enze; Jiang, Kaili; **Liu, Kai***; Zhang, Xinping*. Wafer-scale freestanding vanadium dioxide film. *Science Advances*, 2021, 7, eabk3438.
 7. Wang, Bolun; Wang, Xuewen; Wang, Enze; Li, Chenyu; Peng, Ruixuan; Wu, Yonghuang; Xin, Zeqin; Sun, Yufei; Guo, Jing; Fan, Shoushan; Wang, Chen; Tang, Jianshi; **Liu, Kai***; Monolayer MoS₂ Synaptic Transistors for High-Temperature Neuromorphic Applications, *Nano Letters*, 2021, 21, 10400.
 8. Wang, Bolun; Peng, Ruixuan; Wang, Xuewen; Yang, Yueyang; Wang, Enze; Xin, Zeqin; Sun, Yufei; Li, Chenyu; Wu, Yonghuang; Wei, Jinquan; Sun, Jingbo; **Liu, Kai***. Ultrafast, Kinetically Limited, Ambient Synthesis of Vanadium Dioxides through Laser Direct Writing on Ultrathin Chalcogenide Matrix. *ACS Nano*, 2021, 15, 10502.
 9. Wang, Bolun; Luo, Hao; Wang, Xuewen; Wang, Enze; Sun, Yufei; Tsai, Yu-Chien; Zhu, Hui; Liu, Peng; Jiang, Kaili; **Liu, Kai***. Bifunctional NbS₂-Based Asymmetric Heterostructure for Lateral and Vertical Electronic Devices. *ACS Nano*, 2020, 14, 175.
 10. Wang, Bolun#; Sun, Yufei#; Ding, Hanyuan#; Zhao, Xuan#; Zhang, Lei; Bai, Jingwei*; **Liu, Kai***. Bioelectronics-Related 2D Materials Beyond Graphene: Fundamentals, Properties, and Applications. *Advanced Functional Materials*, 2020, 30, 2003732.
 11. Sun, Yufei; Pan, Jinbo; Zhang, Zetao; Zhang, Kenan; Liang, Jing; Wang, Weijun; Yuan, Zhiquan; Hao, Yukun; Wang, Bolun; Wang, Jingwei; Wu, Yang; Zheng, Jingying; Jiao, Liying; Zhou, Shuyun; Liu, Kaihui; Cheng, Chun; Duan, Wenhui; Xu, Yong*; Yan, Qimin*; **Liu, Kai***. Elastic Properties and Fracture Behaviors of Biaxially Deformed, Polymorphic MoTe₂. *Nano Letters*, 2019, 19, 761.
 12. Ren, Hongtao; Xiong, Zixin; Wang, Enze; Yuan, Zhiquan; Sun, Yufei; Zhu, Kunlei; Wang, Bolun; Wang, Xuewen; Ding, Hanyuan; Liu, Peng; Zhang, Lei*; Wu, Junqiao; Fan, Shoushan; Li, Xiaoyan*; **Liu, Kai***. Watching Dynamic Self-Assembly of Web Buckles in Strained MoS₂ Thin Films. *ACS Nano*, 2019, 13, 3106.
 13. Luo, Hao; Wang, Bolun; Wang, Enze; Wang, Xuewen; Sun, Yufei; Li, Qunqing; Fan, Shoushan; Cheng, Chun*; **Liu, Kai***. Phase-transition modulated, high-performance dual-mode photodetectors based on WSe₂/VO₂ heterojunctions. *Applied Physics Reviews*, 2019, 6, 041407.
 14. Jin, Xiang; Tan, Hengxin; Wu, Zipeng; Liang, Jieun; Miao, Wentao; Lian, Chao-Sheng; Wang, Jiangtao; **Liu, Kai***; Wei, Haoming; Feng, Chen; Liu, Peng; Wei, Yang; Li, Qunqing; Wang, Jiaping; Liu, Liang; Li, Xide*; Fan, Shoushan; Duan, Wenhui*; Jiang, Kaili*. Continuous, Ultra-lightweight, and Multipurpose Super-aligned Carbon Nanotube Tapes Viable over a Wide Range of Temperatures. *Nano Letters*, 2019, 19, 6756.
 15. Sun, Yinghui; Wang, Rongming; **Liu, Kai***. Substrate induced changes in atomically thin 2-dimensional semiconductors: Fundamentals, engineering, and applications. *Applied Physics Reviews*, 2017, 4, 011301.